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Randallstown, Maryland

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VOLUME I, SUMMARY

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A STUDY OF THE PERFORMANCE OF AN ASTRONAUT DURING INGRESS AND EGRESS MANEUVERS THROUGH AIRLOCKS AND PASSAGEWAYS

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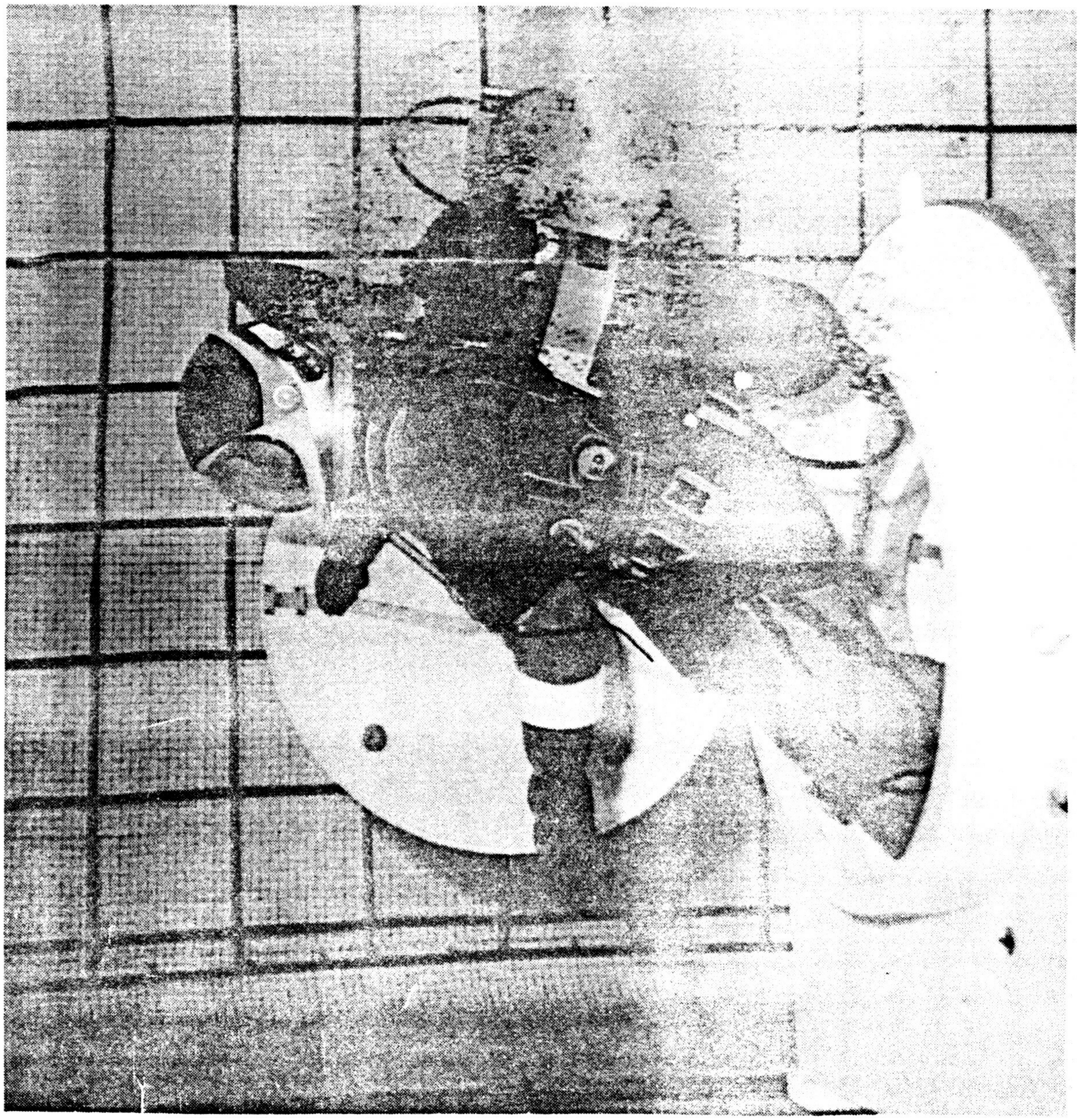

ABSTRACT

The performance characteristics of a pressure-suited astronaut during ingress-egress through a cylindrical, manually operated airlock were studied by water immersion simulation techniques. The buoyancy force induced by water displacement of a totally immersed subject was used to counteract his adjusted total weight to provide the simulated weightless environment. The subject performed a real-time ingress-egress maneuver as determined by functional task analysis of a representative mission.

The following airlock operational characteristics were investigated by factorial replication:

- *The effect of airlock geometry and volume on total performance.*
- *The effect of hatch geometry, diameter and operation direction on performance.*
- *The contribution of torque requirements, hardware placement and motion aids to the problems and procedures comprising ingress-egress and manned replenishment.*

Correlation to actual weightless conditions was provided by similarity comparison with experiments performed aboard zero gravity research aircraft.

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SUMMARY

The National Aeronautics and Space Administration currently planned space missions include manned maneuvers requiring extravehicular task performance. During these maneuvers the astronaut will operate in an anthropomorphic, full pressure suit at pressures of 3.5 PSIA or greater.

In the early phases of manned space exploration, with no provisions for airlocks, a simple hatch is to be used for the transition to space. The Apollo mission is the first to incorporate an operational airlock. This airlock functions to provide internal crew transfer between the command module and the LEM.

An airlock, in general, comprises an airtight structure having two hatches connected by an intervening passageway. The airlock permits ingress and egress through the airtight hull without requiring depressurization of the space vehicle, It is sized to accommodate the transfer of crew and replenishment materials and can be either manually or automatically operated by one or more astronaut crew members.

In a previous study, NAS1-2164, ENVIRONMENTAL RESEARCH ASSOCIATES, investigated the considerations involved in the trade-off between spatial restrictions, configuration and seal leakage. This study resulted in the conceptual design of two airlock configurations. The first a cylindrical geometry structure of 28 inch diameter, has been used at LRC in a seal test program. The second airlock, a 48" diameter

cylindrical structure having a length of 72 inches, was constructed as a full scale model of transparent plastic by NASA-LRC. It includes an oblong door on one end, a circular door on the other end, and a circular side door. This airlock was employed in Phase I of this contract, NAS1-4059, which demonstrated the techniques of water immersion simulation as applied to airlocks and ingress-egress procedures.

This program was established as an experimental study to determine the effects of the weightless (traction-free) environment on the performance of a pressure-suited astronaut (subject) during ingress-egress maneuvers through the 48" x 72" airlock.

This program provided the capability to study the effect of spacecraft airlock configurations and hardware on weightless performance of a pressure suited astronaut and to determine airlock design criteria and performance specifications.

The secondary objective of this program was the development and validation of a combined simulation technique capable of producing a tractionless environment for a human subject while allowing six degrees of freedom of motion.

The simulation technique provided an external state of weightlessness i.e. a condition wherein the subject could not utilize the effect of gravity to provide necessary body reaction forces or traction. The majority of the Phase II experiments were conducted in the water immersion mode of simulation

Simulation of weightless environment by water immersion as developed in this program requires that the complete weight of the subject and associated equipment be counter-balanced by buoyancy forces due to immersion in the water medium.

The undesirable effects of drag, on performance in the water immersion mode proved to be small. The drag produced decelerations for the ingress-egress maneuver performance in the water immersion mode were on the order of 0.7 Ft/sec^2.

An auxiliary method for weightless task simulation was employed in this study comprising balanced gravity flights in the C-131 B aircraft. This maneuver, although of short duration, closely reproduces actual weightless conditions as experienced in earth orbital space.

The basic ingress-egress maneuver requires the subject to unlatch and open a door; enter the airlock; make a complete turnaround; close and latch the door; make a second turnaround; unlatch and open the second door; exit the airlock and finally close and latch door. These tasks are shown in Figures 1-3.

Although variations in the direction of travel (inward or outward door opening), in suit pressure and in hatch diameter had a significant effect on task performance, the subjects successfully accomplished all of their task assignments.

Only three subtasks of the seven comprising the basic maneuver were particularly affected by simulated weightlessness although not all in the same fashion.

Ingress-egress maneuvers were additionally performed using a torque device to simulate the latch action of the model airlock. The test subject was able to apply torque by using body inertia external to the airlock and by using hand and foot holds while internal to the airlock.

Experiments involving position and placement of internal operating equipment showed that although the subject could see and reach any position, the degree of facility varied for different positions and performance deteriorated with time. These tests also pointed out difficulties of controlling hand-held equipment.

During the course of the ingress-egress task performance experiment evaluations were conducted utilizing hand-holds, tetherlines and fixed railings. These initial tests clearly showed the value of these motion aids but, at the same time, indicated problems. The handholds internal to the airlock were useful in aiding a turnaround but also were hazardous. In one instance the subjects helmet visor took a sharp blow during turnaround. While external tether line allowed the subject to retrieve himself, the fixed bar gave him much greater control and the ability to preposition himself for reentry into the airlock. The use of these external motion aids affected the stability of the airlock. A comparison of the visual and performance aspects of ingress-egress in the various simulation modes is given in Figure 4.

CONCLUSIONS

Operations of pressure-suited subjects during the real-time performance of a representative manual ingress-egress maneuver through a cylindrical airlock of 48 inch diameter by 6 feet length were assessed by water immersion simulation techniques. The subjects were filmed during repetitive trials and the position-velocity time profiles of the maneuvers were analyzed for three simulation modes; ground-normal gravity, aircraft-zero gravity, and water immersion-neutral buoyancy. Performance data was presented for the following replicated parameters;

- Subject
- Suit Type
- Suit Pressure Level
- Hatch Configuration
- Hatch Diameter
- Hardware Location

Demonstrations of the problems and procedures comprising the application of torque during ingress-egress, manual replenishment thru airlock and the employment of external motion aids such as fixed bar and tethers were accomplished.

The experimental program performed in conjunction with NAS1-4059, Phases I and II engenders the following conclusions:

1. A 48" diameter 6' length airlock passageway with 32" circular hatches is sufficient, from a space standpoint, for an astronaut to adequately perform a manual ingress-egress maneuver.
2. Counter rotation to applied torques, and movement due to applied linear forces due to lack of gravity dependent body reaction forces must be counteracted to insure adequate operation.
3. Hatch diameters less than 26" should not be utilized due to impediment to free travel and suit interactions.
4. Ingress-egress maneuvers in airlocks of 48" diameter or less requiring internal turnaround of a pressurized suited astronaut dictate strengthening of the suit faceplate to prevent accidental depressurization.
5. Airlock hardware requiring operation by an astronaut in a pressurized suit must be sized to accommodate the lack of tactual and visual ability concommitant with FPS operation.
6. Airlock passageways should remain as free of hardware appurtenances as design factors dictate to prevent suit interaction.
7. Water immersion simulation of weightless, low velocity, restricted volume task performance, particularly involving pressurized suited subjects is valid and further could adequately serve as a real-time task trainer.

RECOMMENDATIONS

The performance of the series of experiments on weightless ingress-egress in Phases I and II of this contract have engendered the following recommendations for future effort in this area. These recommendations fall into two general classes; extension of the series of experiments and demonstrations previously performed to gather data of increased statistical depth and demonstration of several new areas of application in order to ascertain the operational and safety aspects of such experiments. Therefore the following recommendations are made:

- Performance of ingress-egress tasks to provide statistical replication subject, learning, fatigue.
- Simulation of a rescue task.
- Performance of ingress-egress tasks with variable dimension airlock to determine performance/space envelopes.
- Simulation of astronaut tasks with variation of gravity level.
- Evaluation of task performance in other airlock configurations.
- Correlation of task performance with subject energy inputs.
- Establish procedures and training requirements for suited astronaut weightless task performance.

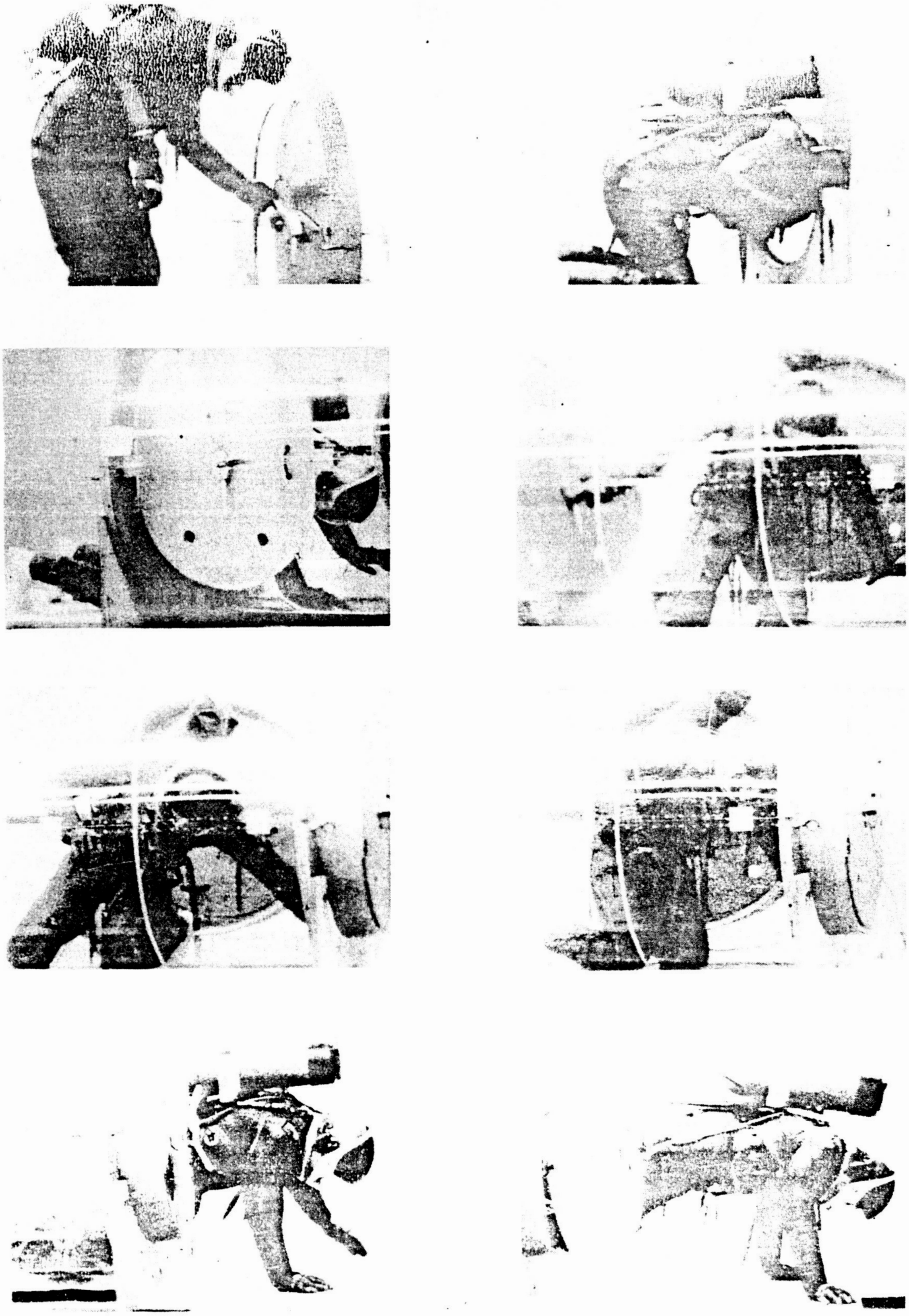


Figure 1. Ingress-Egress Performance- Ground Normal Gravity Mode

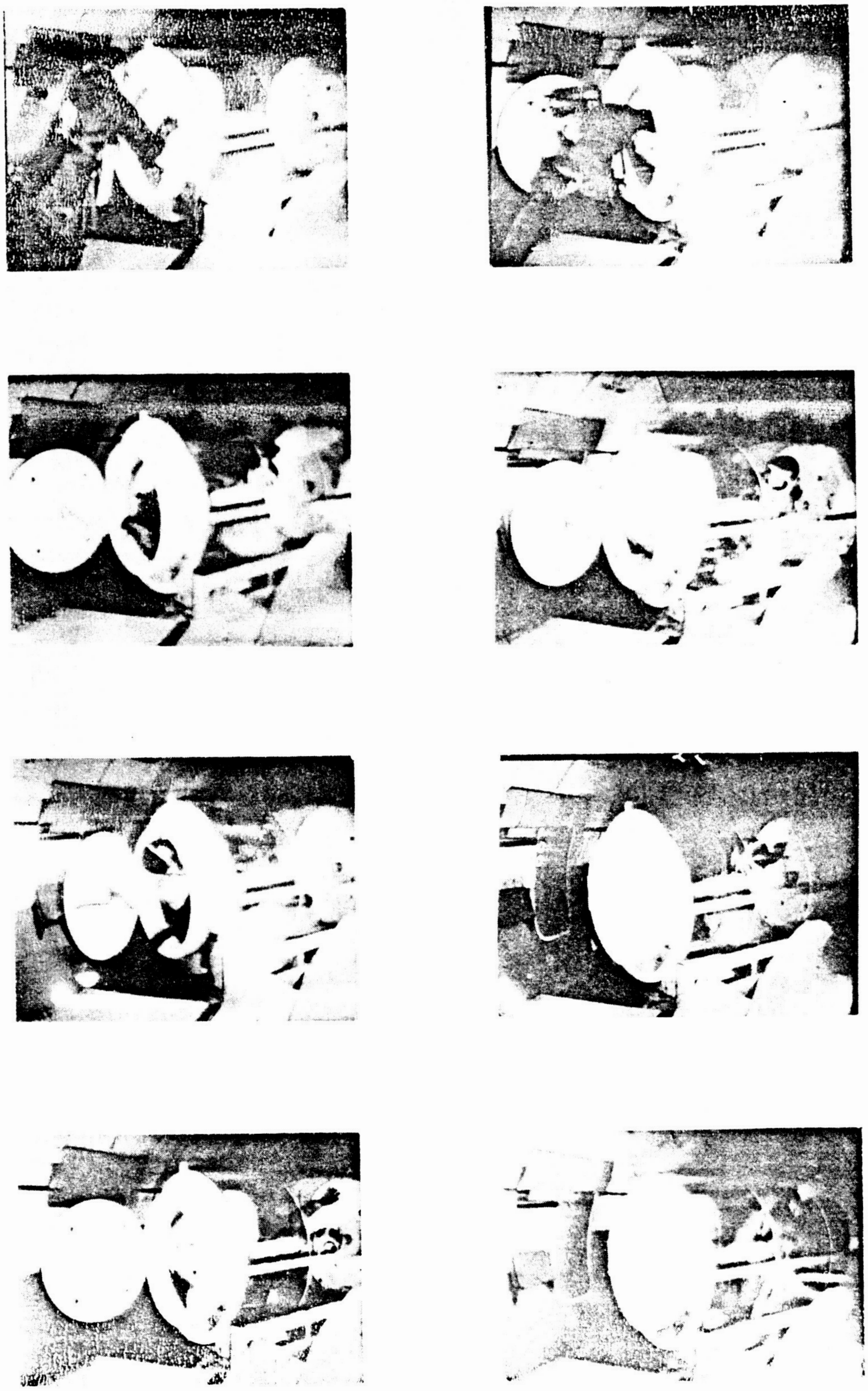


Figure 2. Ingress-Egress Task Performance-Aircraft Zero Gravity Mode

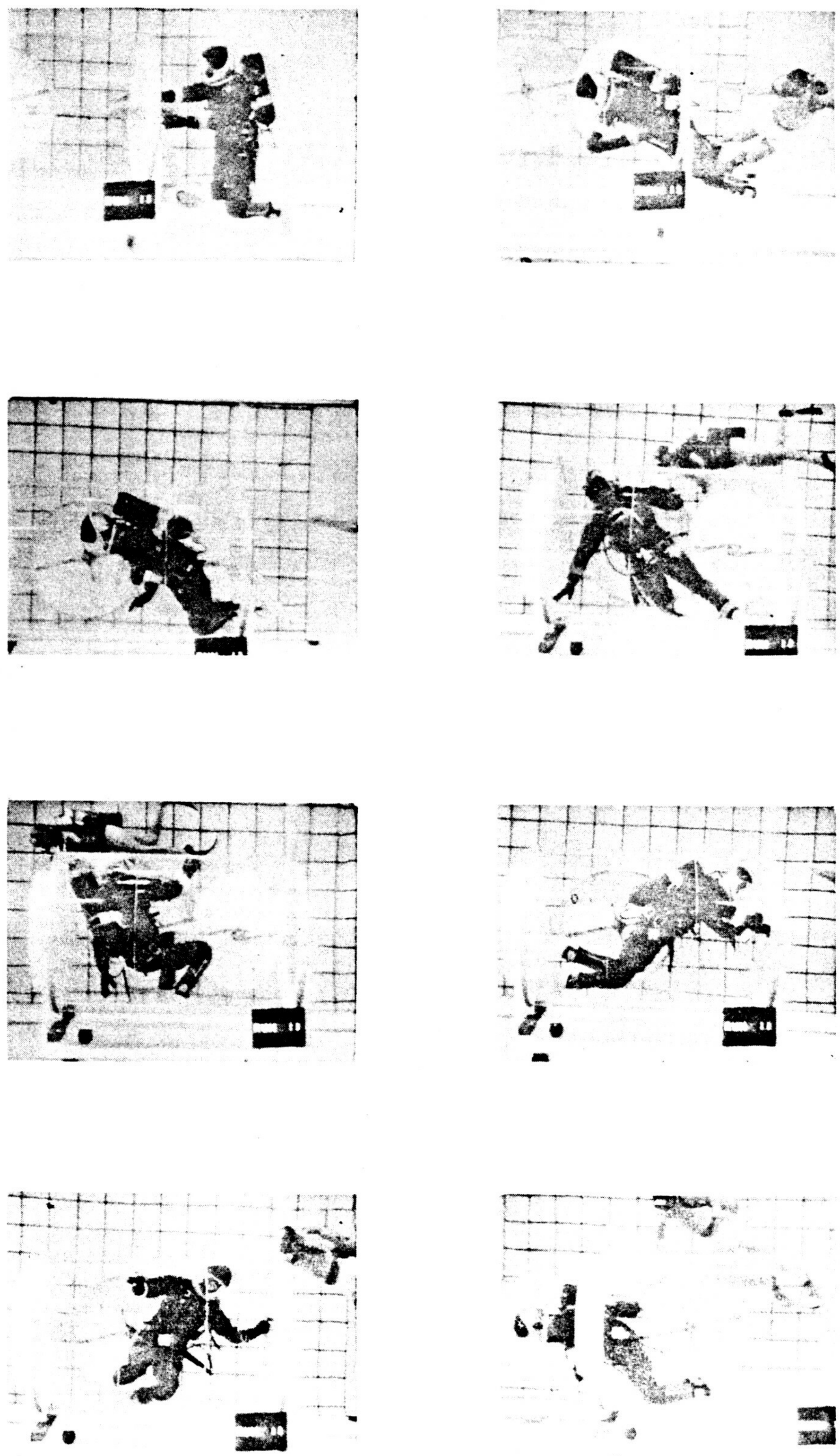
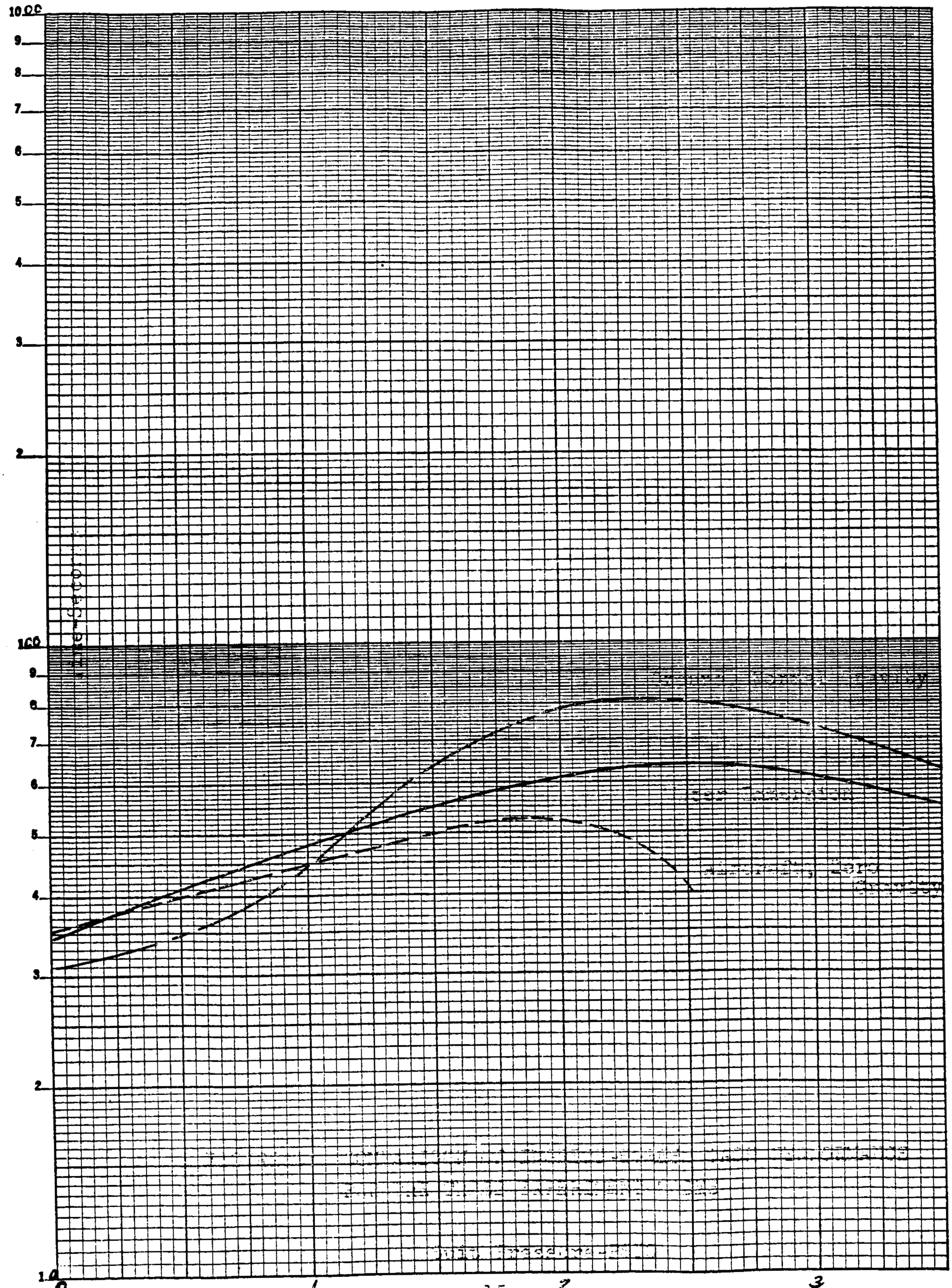


Figure 3. Ingress-Egress Task Performance- Water Immersion Mode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